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MULTITASK PERFORMANCE: PREDICTING SUCCESS IN NAVAL AVIATION PRIMARY FLIGHT TRAINING

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PENSACOLA FLORIDA

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SUMMARY PAGE

THE PROBLEM

Attrition in undergraduate naval aviation training represents a costly problem. An average one in four student naval aviators fails to complete training. This study represents an attempt to reduce aviator attrition through improved selection. A multitask experiment simulating certain motor control and communication requirements characteristic of flight was conducted to determine relative strengths of several performance measures as predictors of primary flight training success.

FINDINGS

A Psychomotor Task (PMT) and a Dichotic Listening Task (DLT) performed under single-task conditions were found to be significantly related ($p < .05$) to a primary flight training pass/fail criterion. Two separate multitask DLT measures also correlated with the pass/fail criterion and at higher levels of statistical significance ($p < .01$) than the single-task measures. The results indicate that various single- and multitask measures are significantly related to primary flight performance, and further reveal that the component test measures may be better predictors under multitask than under single-task conditions.

RECOMMENDATIONS

Additional research using larger samples and additional multitask tests is indicated.

Acknowledgments

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INTRODUCTION

A battery of perceptual/cognitive psychological tests has been developed at the Naval Aerospace Medical Research Laboratory, Naval Air Station, Pensacola, Florida to support the empirically-based derivation of performance-based biomedical selection and assessment standards for naval aviators. Since previous research (8, 1, 11, 7) suggests that proficient time-sharing performance is important for success in aviation training, dual-task structures are currently being evaluated in an attempt to enhance the battery's ability to predict success in naval aviation training. Tests are considered for inclusion in the battery based upon reliable demonstration of their predictive validity.

A previously reported traditional dual-task experiment conducted at this laboratory (4) indicated that the performance of 60 subjects on the psychomotor portion of a combined psychomotor and dichotic listening task was significantly improved when a vocal, as opposed to manual, response mode was employed for dichotic listening. The current investigation explored the potential utility of subjects' dual-performance on the psychomotor task (PMT) and dichotic listening task (DLT) for naval aviator selection. The PMT requires subjects to simultaneously center two visually presented cursors on fixed targets of a CRT screen. To accomplish this task, coordinated movement of a floor-mounted control stick and foot pedals is required. The DLT first requires subjects to attend to auditory information presented to one ear, while ignoring similar information presented to the opposite ear, and then after considering an auditory cue, to switch attention rapidly to the previously unattended ear, or maintain attention to the previously attended channel. Thus, the joint performance of these two tasks requires the management of attention not only between tasks, but also within tasks.

It is probable that within- and between-aspects of task attention management are important skills in flying. To test this assumption, single- and dual-task data from a sample of student naval aviators were collected and maintained until primary flight training outcomes (pass/fail) became available. The present study is a preliminary validation of one potential dual-task component of the test battery.

Method

Subjects. Sixty student naval aviators performed the PMT and DLT tasks separately and in combination. The subjects were volunteers awaiting physical qualification and subsequent entry into either the naval flight training program or naval flight officer training program. Of the 60 subjects, 50 eventually entered primary flight training at Naval Air Station, Whiting Field, Florida. Forty-five successfully completed undergraduate primary flight training; five failed.

Apparatus and Procedure. The PMT and DLT were initially performed separately so that subjects could become familiar with task requirements, apparatus, and response modalities. Next, the two tasks were performed simultaneously. A diagram of the experimental apparatus is presented in Figure 1.

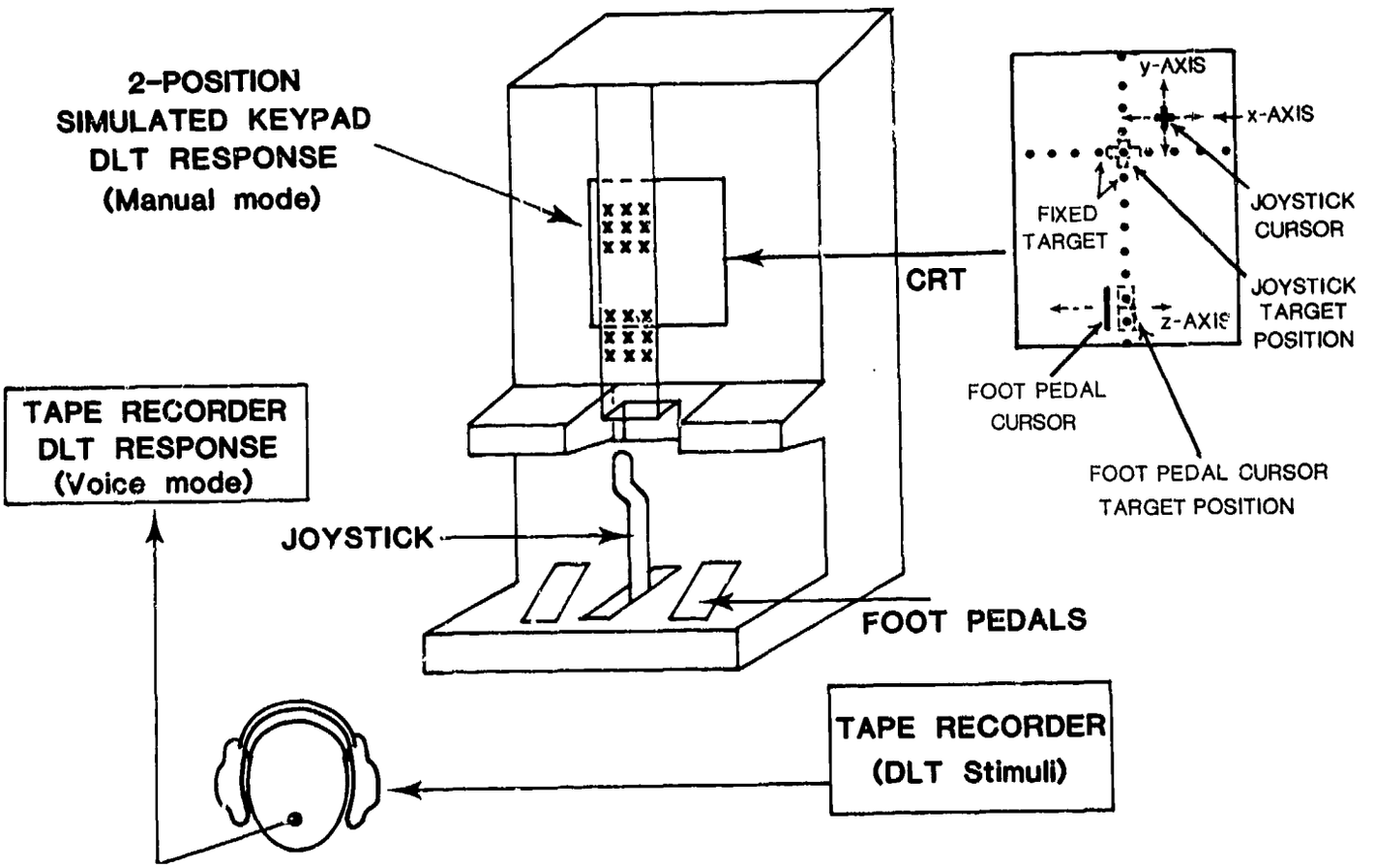

Figure 1. Experimental Apparatus

Psychomotor Task (PMT). Subjects were required to maintain two computer-generated cursors on fixed targets presented on a CRT screen, using the floor-mounted control stick and foot pedals of a Systems Research Laboratory Psychomotor Test Device (Fig. 1). The subject manipulated the control stick with his right hand to control one cursor (X, Y movement) and the foot pedals in order to control the second cursor (Z movement). Performance data were recorded during four consecutive 5-min test sessions. Sessions were separated by rest periods of 90 sec. Tape recorded instructions were presented via a cassette tape player and Koss K/6a headphones. Performance scores were machine-generated cumulative error scores for each of the 5-min sessions. The total error score is the sum of the linear deviations of the cursors from an ideal or "target" position on each of three movement axes (X, Y, and Z) of the visual display.

Dichotic Listening Task (DLT). The DLT was patterned after that developed by Gopher (2) and Gopher & Kahneman (3) and subsequently modified at this laboratory (5). The DLT consisted of letter-digit string sets of 24 listening trials for each of 3 counterbalanced response modalities.

Written, keypad, and verbal response conditions were employed. The subjects were instructed to direct attention to one ear while ignoring the other, and correctly report the nine digits per trial, presented to the attended-to ear in the sequence of occurrence. An example DLT trial is depicted in Figure 2. Each set of 24 listening trials employed a different response mode--written, keypad, or vocal. The three sets of listening trials were separated by 90 sec during which time the test administrator recited the instructions for the subsequent set of listening trials. A dual-channel tape recorder (Nagra IV-SJ) and binaural headphones (Koss K/6a) were used to present the letter-digit strings at a listening level of 72dB/Leq (re:20 Pa). A clear plastic keypad template was located on the PMT device either centered in the field of view horizontally and vertically (design eye level, i.e., position one), or at a lower but horizontally centered location (approximately 30^{o} below design eye, i.e., position two). Half of the subjects used keypad position one, the remainder used keypad position two. Subjects were instructed to make keypad responses with the left hand, while maintaining the right hand on the PMT control stick. Keypad responses were visually monitored and verbally recorded on a cassette recorder by the test administrator. The vocal responses were recorded on a single channel tape recorder (Nagra III N) via a condenser microphone that lightly touched the subject's lips. Written responses were marked by the subjects on an answer sheet. The single-task performance measure for the DLT was simply the number of correct responses per 24 trials. There were 216 correct responses possible for each set of 24 DLT trials.

PART I

Left Ear R 8 N S M Y 2 G B 7 F L 6 R L 5

"Right" (Vocal Channel "attend" Command)

Right Ear Y L 3 S R 4 F Z 9 X F Ø F N 1 L

PART II

Left Ear B F 4 3 7 9

"Left" (Vocal Channel "attend" Command)

Right Ear G L 1 5 6 2

Figure 2. DLT Trial Example

Multitask (PMT, DLT). For the multitask condition, subjects performed two sessions of the DLT and PMT simultaneously (a 12-trial DLT and a 5-min PMT for each of 2 DLT response modalities). The order of keypad and vocal response modes was counterbalanced across subjects so that half used the keypad mode for the first multitask session, and half used the vocal mode. The onset of the DLT occurred 30 sec after the onset of the PMT and terminated 1.5 sec before PMT cessation. Performance measures for the PMT and DLT in the multitask conditions were identical to those of the single-task conditions except that multitask DLT performance was based on 12 rather than 24 trials. Dichotic Listening Task response methods and order of presentation of the PMT and DLT were counter-balanced across subjects and both single- and dual-task experimental conditions. One half of the subjects used keypad position one while the remainder used the second keypad

position throughout all experimental conditions. A subject is shown performing in the multitask condition in Figure 3.

Figure 3. A subject performs in the multitask PMT and DLT keypad response condition.

Selection Test Measures. U. S. Naval and Marine Aviation Selection Battery scores were obtained for each of the 50 subjects who entered flight training subsequent to the experiment. The battery consists of the Aviation Qualification Test (AQT) and the Flight Aptitude Rating (FAR). The AQT is a general ability test of verbal and quantitative aptitude. The FAR is comprised of a Spatial Apperception Test, a Mechanical Comprehension Test, and a Biographical Inventory. All subjects completed these tests prior to receiving orders for flight training. In addition, pass/fail (P/F) results as well as primary flight grades (PFG) were obtained for each subject as these criteria became available.

Data Analysis. Normative and correlational statistical analyses were conducted to derive means and standard deviations and evaluate the strengths of the relationships among the various measures. Multiple regression statistical analysis was used to evaluate the strength of single- and multitask measures as predictors of performance in the primary phase of naval aviation undergraduate pilot training.

Results

Descriptive Statistics. The means and standard deviations for the single- and multitask measures for all tasks across all conditions are presented in Table 1. Since the DLT trials differ from the single- to the multitask conditions, the DLT means were converted to percent correct (in parentheses) and included in Table 1 for purposes of comparison.

The correlation matrix in Table 2 indicates statistically significant correlations between various DLT and PMT measures in both single- and multitask conditions. For example, the correlation between single-task written DLT performance (measure 5) and single-task PMT (session 3, measure 3) is $\underline{r} = -.69$ ($\underline{p} < .01$). This inverse relation results because the PMT score is an error measure (high score = high error), while the DLT score is a number correct score (high score = high correct). Thus, in Table 2, a negative correlation between PMT and another measure means desired performance is positively correlated between the two. In the multitask conditions, DLT scores were also related to PMT performance. The correlation between the vocal DLT multitask measure (measure 11) and PMT error (measure 10) as recorded during simultaneous performance is statistically significant ($\underline{r} = -.53$, $\underline{p} < .01$). Similar results were found between PMT multitask error (measure 8) and the keypad DLT score (measure 9) in the multitask condition ($\underline{r} = -.35$ $\underline{p} < .05$). As expected, the single-task psychomotor measures were all significantly related, the highest correlation ($\underline{r} = .84$, $\underline{p} < .01$) resulting from sessions 3 and 4. Single-task DLT performance (measures 5, 6, and 7) was also significantly related. The highest correlation ($\underline{r} = .71$, $\underline{p} < .01$) was between the written and vocal response modes (measures 5 and 7). In the multitask condition, the DLT keypad and vocal response modes (measures 9 and 11) were highly correlated ($\underline{r} = .89$, $\underline{p} < .01$) as were the two psychomotor multitask scores (measures 8 and 10, $\underline{r} = .87$, $\underline{p} < .01$). Psychomotor Task single- and multitask measures and DLT single- and multitask performance were significantly correlated as well. In fact, nearly all of the Table 2 correlations are statistically reliable. The correlations among selection measures 12 and 13 with the other variables are exceptions. The AQT was unrelated to any single- or multitask measure. However, FAR scores proved to be significantly related

to single-task PMT session 1 (r = -.39, p < .01) and session 4 performance (r = -.29 p < .05).

Table 1

Descriptive Statistics for Single- and Multitask Measures and Selection Tests

	Test Measure	Mean	Standard Deviation
SINGLE	1. PMT Session 1, X,Y,Z error combined	19116.36	86.88
SINGLE	2. PMT Session 2, X,Y,Z error combined	11541.20	7885.94
SINGLE	3. PMT Session 3, X,Y,Z error combined	9896.90	5016.57
SINGLE	4. PMT Session 4, X,Y,Z error combined	9550.82	4256.29
SINGLE	5. DLT written response, No. correct	211.48 (97.9%)	7.75
SINGLE	6. DLT keypad response, No. correct	210.60 (97.5%)	5.40
SINGLE	7. DLT vocal response, No. correct	207.52 (96.1%)	10.11
MULTITASK	8. PMT X,Y,Z error (with keypad response DLT)	21816.92	15039.95
MULTITASK	9. DLT keypad response (with PMT)	102.34 (94.8%)	7.62
MULTITASK	10. PMT X,Y,Z error (with vocal response DLT)	14038.10	9939.77
MULTITASK	11. DLT vocal response (with PMT)	101.44 (93.9%)	11.62
SELECTION	12. AQT standard score	5.66	1.68
SELECTION	13. FAR standard score	6.80	2.05

Table 2

Correlation Matrix for Single- and Multitask Measures, and Selection Tests

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1												
2	.401**											
3	.727**	.544**										
4	.520**	.667**	.838**									
5	-.626**	-.131	-.694**	-.443**								
6	-.616**	-.490**	-.523**	-.453**	.540**							
7	-.494**	-.182	-.407**	-.325*	.708**	.544**						
8	.393**	.500**	.501**	.597**	-.385**	-.503**	-.612**					
9	-.708**	-.244	-.782**	-.508**	.869**	.588**	.563**	-.348*				
10	.526**	.298*	.532**	.443**	-.531**	-.468**	-.669**	.873**	-.445**			
11	-.737**	-.243	-.732**	-.457**	.913**	.540**	.644**	-.363**	.887**	-.529**		
12	-.157	-.067	.060	-.021	.058	.104	.147	-.048	.116	-.037	.058	
13	-.388**	-.239	-.223	-.287*	.050	.144	.223	-.254	.144	-.230	.099	.511**

*P(48df)<.05
**P(48df)<.01

See Table 1 for description of numbered variables.

Relation between task performance and training/selection measures. To evaluate the relation of single- and multitask component measures to proficiency in naval aviation primary training, a pass/fail (P/F) criterion was employed. The pass/fail measure is a "traditional" criterion for tri-service military pilot selection and was the basis for the development of the present Navy aviator selection battery, the AQT/FAR (9). In addition, the single- and multitask measures were correlated with primary training flight grades (PFG). The point-biserial (r pbi) correlations between P/F, single- and multitask performance and selection test scores, respectively, are provided in Table 3. The correlations between the various predictor measures and primary training flight grades (PFG) are Pearson product-moment correlation coefficients. These results indicate that one single-task PMT measure (PMT session 1, $r = -.28$, $p < .05$) and one single-task DLT measure (DLT written response, $r = .36$, $p < .05$) were significantly related to the P/F criterion. Two multitask measures--the keypad and vocal DLT multitask measures ($r = .41$, $p < .01$ and $r = .40$, $p < .01$)--were also found to be significantly related to P/F. Likewise, the correlation between FAR and P/F was also found to be statistically reliable ($r = .36$, $p < .05$). Forty-six subjects remained in the flight program sufficiently long enough to receive flight grades. All of the predictor measures (except PMT session 2 in the single-task condition) were related to PFG at the .05 or .01 level of statistical confidence.

Table 3

Relation Between Single- vs Multitask Measures, Selection Tests, and Pass/Fail, Flight Grade Criteria

Measures	Pass/Fail (r pbi; n=50)	Flight Grade (r; n=46)
1. PMT Session 1, X,Y,Z error combined	-.283*	-.459**
2. PMT Session 2, X,Y,Z error combined	-.028	-.289
3. PMT Session 3, X,Y,Z error combined	-.241	-.399**
4. PMT Session 4, X,Y,Z error combined	-.120	-.515**
5. DLT [illegible]ten response, No. correct	.360*	.332*
6. DLT keypad response, No. correct	.162	.338*
7. DLT vocal response, No. correct	.224	.419**
8. PMT X,Y,Z error (with keypad response DLT)	.036	-.378**
9. DLT keypad response (with PMT)	.413**	.433**
10. PMT X,Y,Z error (with vocal response DLT)	-.002	-.323*
11. DLT vocal response (with PMT)	.395**	.382**
12. AQT standard score	.172	.404**
13. FAR standard score	.361*	.421**

*$p < .05$
**$p < .01$

Regression analysis. To statistically determine which measures would predict training performance outcome, forward selection multiple regression analyses (1C) were conducted on the P/F criterion measure. The regression utilized all of the measures in Table 3 with the exception of PFG. The PFG

training measure was excluded from the regression since it becomes available too late in training to be useful as a selection measure.

In the first regression analysis (Table 4), the multitask DLT keypad score (measure 9; R = .41), followed by the FAR (R = .51) and multitask PMT cumulative error (measure 8; R = .58) comprised the multiple regression equation. Applications of analyses of variance and t-tests (see Table 4) indicate that each of these measures contributed significantly to the regression equation; the aggregate of these variables accounted for slightly more than 33% of the variance associated with the P/F criterion ($p < .01$). It is not altogether clear why the PMT multitask measure remained in the regression. The PMT multitask measure was not related to P/F (r = .04), but was significantly related (r = -.35, $p < .05$) to the multitask keypad DLT response score (measure 9). Measure 9 accounted for a preponderance of the variance in P/F. Perhaps the PMT measure served to suppress some portion of the error variance associated with the multitask DLT keypad score. For the interested reader, Guilford (6) provides an explanation of suppression variables and their statistical implication.

Table 4

Forward Selection Multiple Regression, Analysis of Variance, Coefficients and t-Values

Analysis of Variance Source	df	SS	MS	F	p
Total	49	4.500	-	-	
Reg	3	1.501	.500	7.67	.01
Resid	46	2.999	.065	-	

R-Square = .334 R = .577
Adjusted R-Square (shrinkage) = .290 R = .538

	Coefficients	Std. Error	t-Value
Constant	-1.47193	-	-
Measure 9, DLT keypad Response (multitask)	.018315	.005117	3.579**
Measure 13, FAR Selection Test	.054450	.018428	2.955**
Measure 8, PMT X,Y,Z Error (multitask)	.000006	.000003	2.200*

* $p < .05$
** $p < .01$

A second regression analysis (Table 5) was performed in which the selection test measures (AQT, FAR) were forced into the regression in first and second place resulting in a multiple R of .36. The keypad DLT response score (measure 9) then entered the equation and continued to contribute significant and unique variance beyond that provided by the selection tests (R = .51). In this regression, a second multitask PMT cumulative error score (measure 10) rather than PMT multitask cumulative error measure 8 accounted for significant variance, resulting in a total multiple R of .58. The results of the second regression analysis are depicted in Table 5.

Table 5

Forward Selection with AQT, FAR Forced into Regression, Analysis of Variance, Coefficients and t-Values

Analysis of Variance Source	df	SS	MS	F	p
Total	49	4.500	-	-	
Reg	4	1.521	.380	5.746	.01
Resid	45	2.979	.066		

R-Square = .338 R = .581
Adjusted R-Square (shrinkage) = .279 R = .528

	Coefficients	Std.Error	t-Value
Constant	-1.600296	-	-
Measure 12, AQT	- .014372	.025622	- .561
Measure 13, FAR	.059268	.021518	2.754**
Measure 9, DLT keypad Response (multitask)	.019988	.005420	3.688**
Measure 10, PMT X,Y,Z Error (multitask)	.000009	.000004	2.236*

* $p < .05$
** $p < .01$

A third regression analysis (Table 6) was performed to evaluate whether the multitask measures contributed significant additional variance to the regression above that provided by the single-task PMT and DLT keypad scores. This is an important consideration since an automated keypad response DLT has been configured for ongoing selection efforts. In this regression, the AQT and FAR were forced into the equation (as before) in first and second place resulting in a multiple R of .36. Next, the single-task PMT (measure

1) and single-task DLT keypad (measure 6) scores were forced into the equation resulting in a multiple R of .39. The multitask DLT keypad score (measure 9) then entered the equation resulting in a multiple R of .54. Last, the multitask PMT (measure 8) entered the equation resulting in a multiple R of .59. These results demonstrated that the multitask measures continued to make a significant and unique variance contribution to the regression beyond that provided by the selection tests and respective single-task measures.

Table 6

Forward Selection with AQT, FAR, Single-Task PMT and Keypad Response DLT Forced into the Regression, Analysis of Variance, Coefficients and t Values

Analysis of Variance Source	df	SS	MS	F	p
Total	49	4.500	-	-	
Reg	6	1.590	.265	3.914	.01
Resid	43	2.910	.068		

R-Square = .353 R = .594
Adjusted R-Square (shrinkage) = .263 R = .513

	Coefficients	Std.Error	t-Value
Constant	-2.453751	-	-
Measure 12, AQT	- .017206	.026172	- .657
Measure 13, FAR	.070178	.024014	2.922**
Measure 1, Single-Task PMT	.000003	.000003	1.001
Measure 6, Single-Task Keypad	.001965	.009828	.200
Measure 9, Multitask DLT Keypad	.023130	.007343	3.150**
Measure 8, Multitask PMT	.000005	.000003	1.982*

* p = < .05
** p = < .01

A fourth regression analysis (Table 7) was performed to evaluate whether the multitask measures contributed significant additional variance to the regression above that provided by the single-task PMT and DLT written response scores. In this regression (as before), the AQT and FAR were forced into the equation in first and second place, resulting in a multiple R of .35. Next, the single-task PMT (measure 1) was entered, resulting in a multiple R of .39 followed by the single-task DLT written response (measure 5), resulting in a multiple R of .51. The multitask PMT (measure 10) then entered the equation resulting in a multiple R of .59. In this regression, the keypad multitask (measure 9) failed to enter the equation because of its high correlation (r = .87, p < .01) with single-task DLT written performance (measure 5).

Table 7

Forward Selection with AQT, FAR, Single-Task PMT and Written Response DLT Forced into the Regression, Analysis of Variance, Coefficients and t-Values

Analysis of Variance Source	df	SS	MS	F	p
Total	49	4.500	-	-	
Reg	5	1.590	.318	4.803	.01
Resid	44	2.911	.066		

R-Square = .353 R = .594
Adjusted R-Square = .280 R = .529

	Coefficients	Std.Error	t-Value
Constant	-4.450050	-	-
Measure 12, AQT	- .015802	.025705	- .615
Measure 13, FAR	.071751	.023637	3.040**
Measure 1, Single-Task PMT	.000001	.000003	.278
Measure 5, Written Response DLT	.022558	.006732	3.351**
Measure 10, Multitask PMT	.000012	.000005	2.540*

* p = < .05
** p = < .01

DISCUSSION AND CONCLUSIONS

Our results indicate that a single-task psychomotor measure and a single-task dichotic listening measure were significantly related to a pass/fail (P/F) criterion in the primary phase of Navy flight training. However, two multitask DLT measures (DLT keypad response and DLT vocal response) were found to be even more highly correlated with P/F. The results indicate, moreover, that the DLT keypad response measure, taken under multitask conditions, accounts for variance in predicting primary flight performance beyond that accounted for by the same measure taken under single-task conditions.

The application of one multiple regression analysis indicated that the multitask DLT keypad response measure, followed by the FAR selection test measure, were the strongest predictors of criterion performance. A multitask PMT measure also contributed significantly. Each of these measures made a unique and significant contribution to the regression, resulting in a multiple R of .58.

In a separate regression analysis, AQT and FAR scores were forced into the equation as first and second variables, respectively. The DLT keypad multitask response measure subsequently entered the equation followed by a PMT multitask error score. As before, each of these latter measures made a unique and significant contribution to the regression, resulting in a R of .58. The importance of the findings provided by the second regression analysis was the demonstration that the multitask measures accounted for unique variance beyond that accounted for by current selection tests.

A third regression analysis demonstrated that specific multitask measures (DLT keypad response measure 9 and PMT measure 8) contributed significant and unique variance beyond that provided by their respective single-task scores and selection tests. This finding has important implications because of the emphasis on automating the tasks within the selection battery. Automating the various selection tasks will allow administration in multiple locations without the requirement for a sophisticated test monitor at each testing site. In addition, the DLT is presently configured in an automated keypad response mode for selection evaluation at the laboratory.

A fourth regression analysis demonstrated that the incorporation of dissimilar single- and multitask DLT measures diminished the contribution of multitask keypad performance. That is, when a single-task written response DLT score was forced into the equation initially, multitask DLT keypad response performance failed to contribute a significant amount of added variance because of the high correlation ($r = .87$, $p < .01$) between the two DLT scores.

The finding of a significant relation between the PMT and the DLT is surprising, especially since there appears superficially at least to be little overlap in the performance requirements of the two tasks. Whereas the PMT is a visual/motor task, the DLT is an auditory/verbal task. It is also surprising that DLT multitask performance was found to be significantly related to P/F while PMT multitask scores were not.

The present evaluation of single- and multitask psychomotor and dichotic listening measures indicated that (1) single- and multitask measures were predictive of a pass/fail flight training criterion, and (2) that certain multitask measures accounted for additional variance beyond that provided by respective single-task performance. The results were based on a relatively small sample and should be replicated with a larger subject population before final conclusions are drawn. Ultimately, consideration must be given to the economics of the various single- and multitask measures in terms of subject testing time and apparatus costs.

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A multitask experiment simulating certain motor control and communication requirements characteristic of flight was conducted in order to determine relative strengths of several performance measures as predictors of primary flight training success.

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20. (continued)

A single-task psychomotor measure and a single-task dichotic listening measure were found to be significantly related ($p < .05$) to a primary flight training pass/fail criterion. Two separate multitask Dichotic Listening Task measures were also found to be correlated with the pass/fail criterion and at higher levels of statistical significance ($p < .01$) than the single-task measures. The results indicate that various single- and multitask measures are significantly related to primary flight performance, and further reveal that certain component test measures may be better predictors under multitask than under single-task conditions.